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EP 0 513 801 B1

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Description

The present invention relates to a distance measuring apparatus for optically measuring a distance, and, more specifically, to a distance measuring apparatus according to the preamble of claim 1 which is known from DE-A-4 006 989.

DE-A-3 642 196 discloses an optoelectronic collision preventing device for vehicles which upon appearance of an obstacle into the possible collision region provides a signal and can decelerate the vehicle, wherein images depicted by two or more image-pickup optical systems of the possible collision region are investigated by image analysis on possible collision objects.

Particularly, this known device is provided with automatically controllable irises which dependent on the brightness of the monitoring region generate an optimum light intensity on photosensitive semiconductor arrays. The necessary control signals are generated from the image recognition by a microcomputer.

Generally, in a distance measuring apparatus based on a triangulation system and utilizing a two-dimensional image obtained by an image-pickup apparatus, it is essential to adequately determine the level of exposure to which an image-pickup apparatus is subjected for the purpose of accurately measuring a distance to an object, and the level of exposure is determined by an ordinary exposure deciding method for an image pickup apparatus.

Fig. 1 illustrates an exposure control apparatus of a conventional image-pickup apparatus comprising an optical system lens 101, an iris 102, an image sensor 103, a mean value processing circuit 104 and a comparator 105. Image sensor 103 picks up 30 images per second in the case of, for example, a motion picture. Mean value processing circuit 104 obtains a mean value of image signals from image sensor 103. Comparator 105 compares this mean value with a preset reference signal to obtain a deviation which controls an amount of exposure by adjusting iris 102. A mean value of image signals of one picture may be used, but a mean value of image signals of a plurality of successive pictures is usually used.

Fig. 2 illustrates the structure of another conventional exposure control apparatus. This apparatus is called a peak measuring system which employs a system for deciding a level of exposure from the image signal representing the brightest part of an image.

The control apparatus shown includes a peak hold circuit 106. Image signals from image sensor 103 are inputted to peak hold circuit 106 and the image signal representing the brightest part of an image is held for each picture. Comparator 105 compares the held image signal with a reference signal to obtain a deviation which controls iris 102, thereby controlling an amount of exposure.

Also, a system for deciding an amount of exposure from the brightness of a limited region in the periphery of a picture center and a system for sampling several representative points in a picture to decide the level of exposure from a mean value of the brightness of the sampled points have been proposed.

Conventional distance measuring apparatuses control, as explained above, amounts of exposure of image-pickup apparatuses. However, since an image of a distance measurement object is not always picked up in a clear contrast at an adequate exposure level, an error may be generated in a distance calculation, a result of distance calculation may not be used for distance determination, and, in a tracking-type distance measuring apparatus, tracking may be impossible or an erroneous object may be tracked.

It is an object of the present invention to provide a distance measuring apparatus which overcomes such problems as explained above and can accurately measure a distance to an object as well as ensuring accurate tracking of an object.

This object is achieved by the initially defined distance measuring apparatus having the features of the characterizing part of claim 1.

Preferred embodiments are listed in the dependent Claims.

The distance measuring apparatus of the present invention further comprises a tracking means for tracking an object by using an image in the window as a reference image to take correlation of the reference images in a time sequence.

When a difference between mean and peak values of an image signal in the window is equal to or larger than a predetermined value, or when a ratio of a region of an image in the window having a brightness equal to or higher than a predetermined value to the remaining region exceeds a predetermined value, an adequate exposure level can be calculated with a peak value of the image signal in the window.

When the headlights of a vehicle are OFF, an adequate exposure level may be calculated from a mean value of an image signal in the window, while the headlights are ON, adequate exposure can be calculated from a peak value of an image signal in the window.

In the present invention, a window including an object is set in an image picked up by one of image-pickup optical systems so that adequate exposure of the image-pickup optical systems is calculated from an image signal in the window. As a result, an image can be obtained such that the image in the window

displays clear contrast, whereby a more accurate correlation between the image in the window and the image picked up by the other optical system can be achieved. In addition, tracking an object is carried out by taking a correlation of the images in the window in time sequence to thereby provide a more accurate correlation.

When a difference between mean and peak values of an image signal in the window is equal to or larger than a predetermined value or when a ratio of a region of the image in the window having a brightness equal to or higher than a predetermined value to the remaining region exceeds a predetermined value, an adequate exposure level may be obtained by a peak value of the image signal in the window whereby optimum contrast of the image in the window is obtained.

When the headlights of a vehicle are OFF and ON, an adequate exposure level may be calculated by a mean value and a peak value of the image signal in the window, respectively. When the headlights are OFF, in the daytime and an image is bright, an accurate exposure level may be calculated from a mean value of the image signal. When the headlights are ON at night or in a tunnel, an image is dark, but the tail lamps of a leading vehicle are bright, so that an adequate exposure level may be obtained from a peak value of the image signal.

The above and other objects and features of the present invention will become more apparent from the following detail description with reference to the accompanied drawings.

Fig. 1 is a structural diagram of a conventional exposure control apparatus;

Fig. 2 is a structural diagram of another conventional exposure control apparatus;

Fig. 3 is a structural diagram of a first embodiment of a distance measuring apparatus according to the present invention;

Fig. 4 contains diagrams for explaining operation of the first embodiment of a distance measuring apparatus of the present invention;

Fig. 5 is a structural diagram of a second embodiment of a distance measuring apparatus according to the present invention;

Fig. 6 is a structural diagram of a third embodiment of a distance measuring apparatus according to the present invention;

Fig. 7 contains diagrams for explaining operation of the third embodiment of a distance measuring apparatus of the present invention;

Fig. 8 is a structural diagram of a fourth embodiment of a distance measuring apparatus according to the present invention.

Embodiments of the present invention will be described with reference to the accompanied drawings. Fig. 3 illustrates the structure of the first embodiment of a mobile distance measuring apparatus according to the present invention. This distance measuring apparatus comprises a pair of optical system lenses 1L, 1R for image pickup, a pair of irises 2L, 2R, a pair of image sensors 3L, 3R, a pair of image sensor control circuits 6L, 6R, a pair of analog/digital converters 7L, 7R, a pair of memories 8L, 8R, an exposure calculation circuit 9, an image signal processor 10, an image display 11 and a window setting unit 12, in order to measure the distance between a vehicle 13 and the distance measuring apparatus.

Next, operation of the distance measuring apparatus having the structure explained above will be explained. An image of vehicle 13 is picked up by a pair of image sensors 3L, 3R through a pair of optical system lenses 1L, 1R and a pair of irises 2L, 2R. The image signal thus formed is converted to a digital signal by analog/digital converters 7L, 7R and then stored in a pair of memories 8L, 8R. A window W which is set by window setting unit 12 is inputted to image processor 10 and the address of the window is stored in memory 8R. Fig. 4 illustrates images α and β picked up by image sensors 3R, 3L. The entire picture is formed by pixels arranged in m rows and n columns. Window W is set in a shape defined by the p-th row, q-th column, (p+r)-th row and (q+s)-th column in image α picked up by image sensor 3R, and the entire picture and window W are displayed on image display 11.

In order to obtain the distance between vehicle 13 and a pair of pictures picked up by image sensors 3L, 3R, correlation between an image signal S_{ij} within window W formed in image α picked up by image sensor 3R and an image signal S'_{ij} within a hatched region in image β picked up by image sensor 3L is taken to detect from image β the portion most closely matching the image in window W. Mathematically, the following calculation is executed:

$$C(x) = \sum_{j=q}^{q+s} \sum_{i=p}^{p+r} | S_{ij} - S'_{i+x,j} | \qquad (1)$$

where, $-p \leq x \leq m-r$. Assuming that C(x) of formula (1) using x as a parameter takes a minimum value when $x = x_0$, the image in window W well matches the image defined by points $(p+x_0, q)$, $(p+x_0, q+s)$, $(p+x_0+r, q+s)$, $(p+x_0+r, q)$ in image β of image sensor 3L. Therefore, a distance R can be obtained by the following formula (2) from the principle of triangulation:

$$R = f\ell/p_0x_0 \quad (2)$$

where ℓ is a basic line length (the interval between the centers of optical system lenses 1L, 1R), f is the distance between optical system lenses 1L, 1R and image sensors 3L, 3R and p_0 is a pixel pitch in images α, β picked up by image sensors 3L, 3R.

In order to clearly detect a minimum value of C(x) through such calculations as described above, an image must be distinct. Particularly, it is important that an image in window W is distinct and has sufficient contrast in order to measure distance R. Accordingly an adequate level of exposure is essential. Since a conventional distance measuring apparatus decides exposure of an image in accordance with the entire information of a picture, an image in window W does not always have an adequate exposure level.

In the first embodiment of the present invention, an image signal in window W is read from memory 8R and then input to exposure calculation circuit 9 whereby adequate exposure is calculated based on the brightness of the image in window W. Results of this calculation are inputted to irises 2R, 2L and to image sensors 3R, 3L through image sensor control circuits 6R, 6L in order to control openings of irises 2R, 2L and electronic shutter functions of image sensors 3R, 3L. As a result, an exposure level can be controlled over a wide range and the level of exposure to which an image in window W is subjected adequately.

In a calculation for adequate exposure according to the present invention, it is possible that a mean or peak value of image signals in window W and a representative value at an area near the center of window W may be used. Alternatively, an adequate exposure level can be set more accurately by taking a mean value of image signals in window W in daylight and calculating an exposure level using a peak value of an image signal at night considering that a difference between mean and peak values of an image signal become greater than a predetermined value, since tail lamps of a leading vehicle are particularly bright and the circumference is dark. In the case of rear lights or at an exit of a tunnel, if a difference in brightness is large and a region having a brightness greater than a predetermined value occupies more than a predetermined rate of the image in window W, halation is generated. Therefore, calculating a peak value may be desirable.

Fig. 5 illustrates a second embodiment of a distance measuring apparatus according to the present invention, which is interlocked with a headlight switch 14 of a vehicle. In the daytime, since headlights are usually off, exposure calculation circuit 9 detects that headlight switch 14 is turned OFF and operates to calculate an adequate exposure level with a mean value of the image signals within window W. At night or in a tunnel, headlight switch 14 is turned ON to activate the headlights. Therefore, exposure calculation circuit 9 detects the ON condition of headlight switch 14. During the night, since the tail lamps of vehicle 13 is bright and the circumference is dark, an adequate exposure level is calculated based on a peak value of the image signal within window W for the same reason as the first embodiment.

Fig. 6 illustrates a third embodiment of a distance measuring apparatus according to the present invention. The distance measuring apparatus of this embodiment comprises a tracking memory 15 and the remaining structure is the same as the apparatus shown in Fig. 3. For tracking vehicle 13, image α picked up by image sensor 3R at a time $t = t_0$ shown in Fig. 7(a) is stored in memory 8R, and window W is set in the same memory. After the distance between vehicle 13 and the apparatus is calculated by the image signals stored in memories 8R, 8L, the signals stored in memory 8R are transferred to memory 15 and stored therein.

As illustrated in Fig. 7(b), images β, γ picked up by image sensors 3R, 3L at a time $t = t_0 + \Delta t$ after a minute time Δt has passed from time t_0 are stored in memories 8R, 8L. Then the image which suitably matches the images in window W at times t and to stored in memory 15 is detected in image β stored at time $t = t_0 + \Delta t$, and a new window W' is set in memory 8R. After setting new window W', distance R to the vehicle 13 is calculated using image γ stored in memory 8L and window W'. Thereafter, the image signals stored in memory 8R are transferred to memory 15.

The images in window W can be tracked by executing the operations explained above as time passes. The image which matches the image in the window defined by the r-th row, s-th column, p-th row and q-th column set at the time $t = t_0$ is detected in an enlarged region A including window W in the image at time $t = t_0 + \Delta t$. More specifically, the following calculation is executed:

$$C(x, y) = \sum_{j=q}^{q+s} \sum_{i=p}^{p+r} | S_{ij} - S'_{i+x, j+y} | \qquad (3)$$

where $p - u \leq x \leq p + r + u$, $q - v \leq y \leq q + s + v$ and adequate values are set to u and v depending on a value of Δt.

When C(x, y) becomes minimum, the image in enlarged region A suitably matches the image in window W. Window W' at time $t = to + \Delta t$ is defined as the region surrounded by points $(p + x_0, q + y_0)$, $(p + x_0 + r, q + y_0)$, $(p + x_0 + r, q + y_0 + s)$ and $(p + x_0, q + y_0 + s)$ by obtaining parameters x_0 and y_0 at that time. The distance to vehicle 13 found in window W' can be calculated using the principle of triangulation from a couple of images β, γ at time $t = t_0 + \Delta t$ for new window W'. As explained above, the distance to vehicle 13 can be measured continuously by tracking vehicle 13 within window W initially set.

For the purpose of tracking a vehicle without fail and measuring the distance to the vehicle by way of the calculations explained above, the images in windows W, W' should be particularly distinct. Therefore, the image signals in windows W, W' are inputted to exposure calculation circuit 9 of Fig. 6 to determine adequate exposure, either or both openings of irises 2R, 2L and electronic shutter functions of image sensors 3R, 3L are controlled in accordance with a result of calculation and thereby adequate exposure to the images in windows W, W' can be set.

In calculating an adequate level of exposure, it is desirable that a mean value of the image signals in window W, W' is used in the daytime, but that, at night, a more accurate exposure level may be calculated based on a peak value of the image signals within windows W, W' because the tail lamps of vehicle 13 are bright and the circumference is dark. In the case where a difference in brightness is large, for example, in the case of rear lights or at an exit of a tunnel, halation may be generated. In this case, it is desirable to execute calculations based on a peak value of the image signals within windows W, W'.

Fig. 8 illustrates a fourth embodiment of a distance measuring apparatus according to the present invention, also comprising headlight switch 14 and memory 15 as explained above. Exposure calculation circuit 9 detects that headlight switch 14 is in the OFF condition and calculates an adequate level of exposure using mean values of the image signals within windows W, W'. Since switch 14 is turned ON at night or in a tunnel, exposure calculation circuit 9 detects that the headlights are ON. In this case, the level of exposure is calculated in accordance with a peak value of image signals in windows W, W' taking into consideration that the tail lamps of vehicle 13 are bright, the circumference being dark.

As explained above, according to the present invention, a level of exposure of an image-pickup optical system is controlled on the basis of an image signal in a window. As a result, the image signals in the window become distinct, a distance calculation and a calculation for tracking become more accurate whereby accurate distance measurement and tracking can be realized.

Moreover, according to the present invention, since a state of travel of a vehicle, such as in the daytime, at night, or in a tunnel, is identified from the condition of images in a window or an ON-OFF condition of the headlights and an exposure level is determined from a mean or peak value of the image signals in the window in accordance with such a state identification, the image in the window can be set to be more distinct in accordance with circumferential conditions and a distance measurement and tracking of a vehicle can be realized more accurately.

Claims

1. A distance measuring apparatus, comprising:

   a) a pair of image-pickup optical systems (1R,2R,3R;1L,2L,3L) arranged to have a predetermined base line length (1);

   b) a window setting means (12) for setting a window (W) including an object within an image picked-up by one of said image-pickup optical systems (1R,2R,3R;1L,2L,3L);

   c) a distance calculating means (10) for calculating a distance to said object by calculating a correlation between the image in said window (W) and an image picked-up by the other image-pickup optical system;

   characterized by

   d) an exposure calculating means (9) for calculating an adequate exposure level of said image-pickup optical systems (1R,2R,3R;1L,2L,3L); and

e) a control means (6R;6L) for controlling said image-pickup optical systems (1R,2R,3R;1L,2L,3L) in accordance with said adequate level of exposure calculated by said exposure calculating means (9); wherein said exposure calculating means (9) is arranged to calculate said adequate exposure level in accordance with the peak value of an image signal in the window (W) when a difference between the mean and peak values of the image signal in the window (W) is equal or larger than a predetermined value or when a ratio of a region of the image in the window having a brightness equal to or higher than a predetermined value to the remaining region exceeds a predetermined value.

2. A distance measuring apparatus according to claim 1, wherein said exposure calculating means (9) detects an ON and an OFF condition of a headlight switch (14) and accordingly, calculates an adequate exposure level with a mean value of an image signal in the window when the headlight switch (14) is OFF and with a peak value of an image signal in the window when the headlight switch (14) is ON.

3. A distance measuring apparatus according to one of the preceding claims, further comprising:
f) a tracking means (15) for tracking said object by using an image in said window (W) as a reference image to take a correlation of reference images in time sequence.

Patentansprüche

1. Abstandsmeßvorrichtung mit:
a) einem Paar optischer Bildaufnahmesysteme (1R,2R,3R; 1L,2L,3L), welche angeordnet sind, eine vorbestimmte Basislinienlange (1) zu haben;
b) einer Fenstereinstelleinrichtung (12) zum Einstellen eines Fensters (W) einschließlich eines Objektes innerhalb eines Bildes, das durch eines der optischen Bildaufnahmesysteme (1r, 2R, 3R; 1L , 2L, 3L) aufgenommen ist;
c) einer Abstandsberechnungseinrichtung (10) zum Berechnen eines Abstandes zu dem Objekt durch Berechnen einer Korrelation zwischen dem Bild in dem Fenster (W) und einem Bild, das durch das andere optische Bildaufnahmesystem aufgenommen ist;
gekennzeichnet durch
d) eine Aufnahmeberechnungseinrichtung (9) zum Berechnen eines hinreichenden Aufnahmepegels der optischen Bildaufnahmesysteme (1R, 2R, 3R; 1L, 2L, 3L); und
e) eine Steuereinrichtung (6R; 6L) zum Steuern der optischen Bildaufnahmesysteme (1R, 2R, 3R; 1L, 2L, 3L) in Übereinstimmung mit dem hinreichenden Aufnahmepegel, der durch die Aufnahmeberechnungseinrichtung (9) berechnet ist; wobei die Aufnahmeberechnungseinrichtung (9) eingerichtet ist zum Berechnen des hinreichenden Aufnahmepegels in Übereistimmung mit dem Spitzenwert eines Bildsignals in dem Fenster (W), wenn eine Differenz zwischen dem Mittel- und Spitzenwert des Bildsignals in dem Fenster (W) gleich oder größer ist als ein vorbestimmter Wert, oder wenn ein Verhältnis eines Bereichs des Bildes in dem Fenster mit einer Helligkeit gleich oder größer einem vorbestimmten Wert zum Restbereich einen vorbestimmten Wert überschreitet.

2. Abstandsmeßvorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Aufnahmeberechnungseinrichtung (9) eine EIN- und AUS-Bedingung eines Scheinwerferschalters (14) erfaßt und dementsprechend einen hinreichenden Aufnahmepegel berechnet mit einem Mittelwert eines Bildsignals in dem Fenster, wenn der Scheinwerferschalter (14) aus ist, und mit einem Spitzenwert eines Bildsignals in dem Fenster, wenn der Scheinwerferschalter (14) EIN ist.

3. Abstandsmeßvorrichtung nach einem der vorhergehenden Ansprüche, gekennzeichnet durch:
f) eine Verfolgungseinrichtung (15) zum Verfolgen eines Objektes unter Benutzung eines Bildes in dem Fenster (W) als ein Referenzbild zum Nehmen einer Korrelation der Refererenzbilder in einer Zeitsequenz.

Revendications

1. Dispositif de mesure de distance comprenant :
a) un couple de systèmes optiques (1R,2R,3R;1L,2L,3L) de détection d'images agencés de manière à posséder une longueur de ligne de base prédéterminée (1);
b) des moyens (12) de positionnement de fenêtre pour positionner une fenêtre (W) incluant un objet à l'intérieur d'une image détectée par l'un desdits systèmes optiques (1R,2R,3R;1L,2L,3L) de

détection d'images;

c) des moyens de calcul de distance (10) pour calculer une distance par rapport audit objet, au moyen du calcul d'une corrélation entre l'image dans ladite fenêtre (W) et une image détectée par l'autre système optique de détection d'images;

caractérisé par

d) des moyens de calcul d'exposition (9) pour calculer un niveau d'exposition adéquat des systèmes optiques (1R,2R,3R;1L,2L,3L) de détection d'images;

e) des moyens de commande (6R;6L) pour commander lesdits moyens optiques (1R,2R,3R;1L,2L,3L) de détection d'images en fonction dudit niveau adéquat d'exposition calculé par lesdits moyens de calcul d'exposition (9); lesdits moyens de calcul d'exposition (9) étant agencés de manière à calculer ledit niveau d'exposition adéquat en fonction de la valeur maximale d'un signal d'image dans la fenêtre (W) lorsqu'une différence entre la valeur moyenne et la valeur maximale du signal d'image dans la fenêtre (W) est égale ou supérieure à une valeur prédéterminée ou lorsqu'un rapport d'une zone de l'image dans la fenêtre, possédant une luminosité égale ou supérieure à une valeur prédéterminée, à la région restante, dépasse une valeur prédéterminée.

2. Dispositif de mesure de distance selon la revendication 1, dans lequel lesdits moyens de calcul d'exposition (9) détectent un état FERMÉ et un état OUVERT d'un interrupteur de phare (14) et par conséquent calculent un niveau d'exposition adéquat avec une valeur moyenne d'un signal d'image dans la fenêtre lorsque l'interrupteur de phare (14) est OUVERT et avec une valeur maximale d'un signal d'image dans la fenêtre lorsque l'interrupteur de phare (14) est FERMÉ.

3. Dispositif de mesure de distance selon l'une des revendications précédentes, comprenant en outre :

f) des moyens de suivi (15) pour réaliser le suivi dudit objet en utilisant une image dans ladite fenêtre (W) en tant qu'image de référence pour obtenir une corrélation d'images de référence selon une séquence temporelle.

Fig. 1

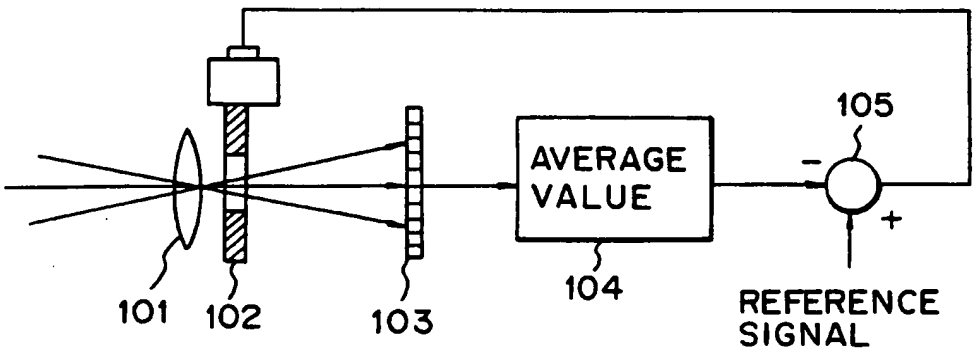

AVERAGE
VALUE
105
104
REFERENCE
SIGNAL
101
102
103

Fig. 2

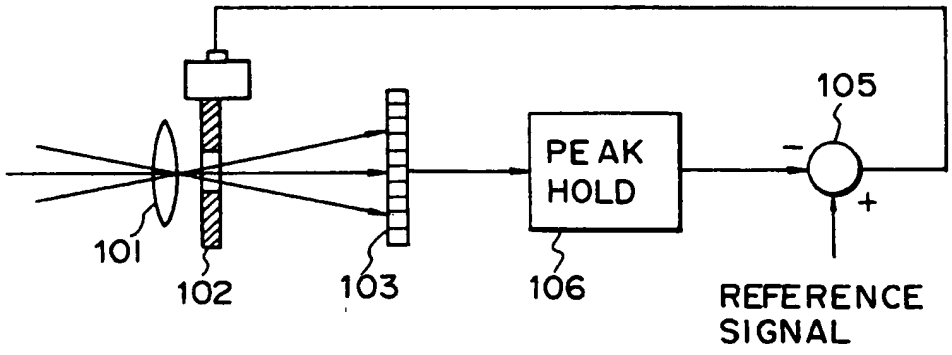

PEAK
HOLD
105
106
REFERENCE
SIGNAL
101
102
103

Fig.3

Fig.3A	Fig.3B

Fig. 3A

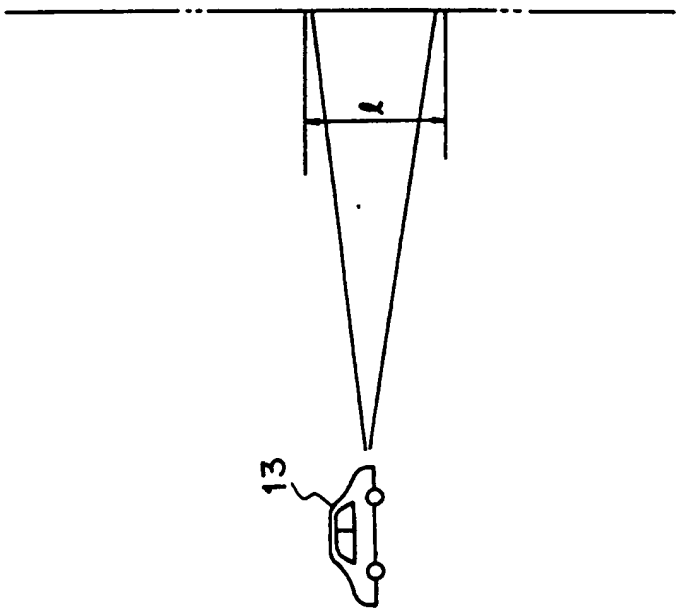


Fig. 3B

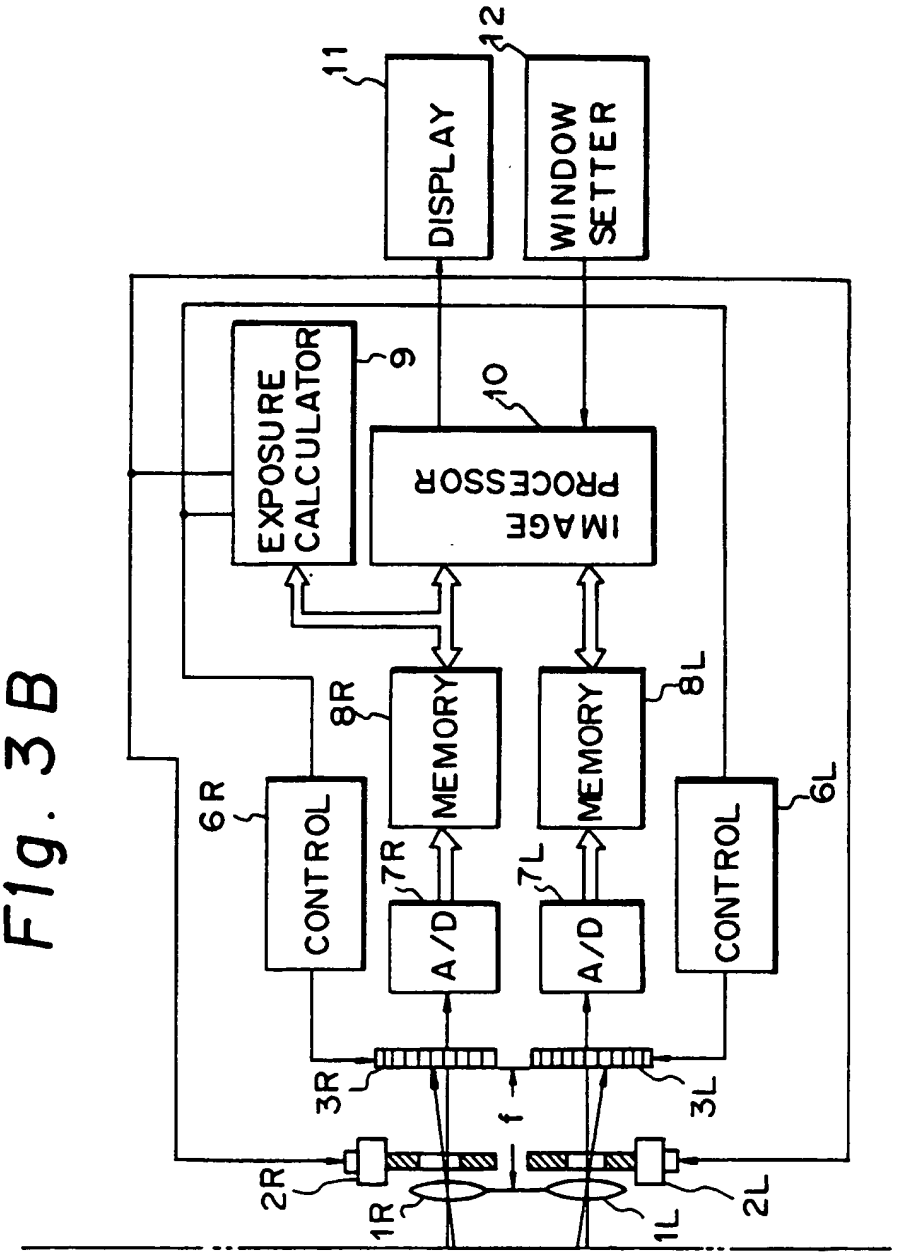
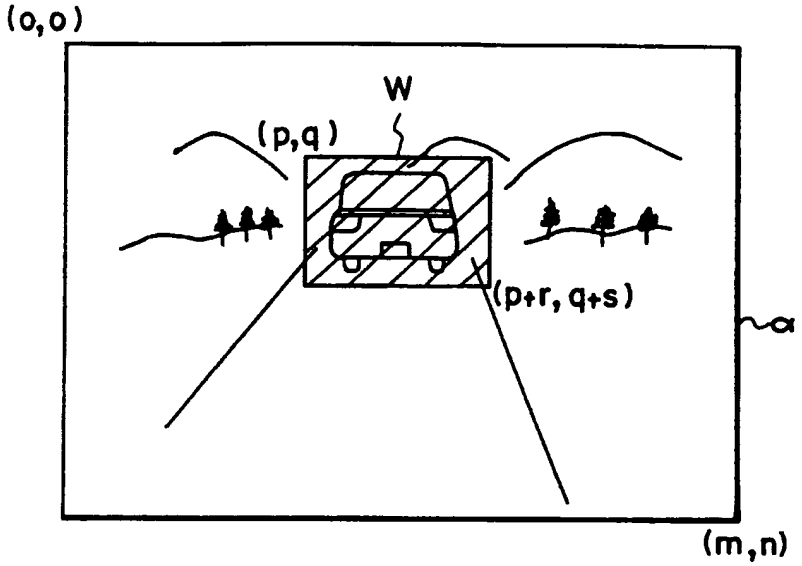

11
DISPLAY
12
WINDOW SETTER
EXPOSURE CALCULATOR
9
10
IMAGE PROCESSOR
8R
MEMORY
MEMORY
8L
6R
CONTROL
7R
A/D
7L
A/D
CONTROL
6L
3R
3L
f
2R
1R
1L
2L

Fig.4



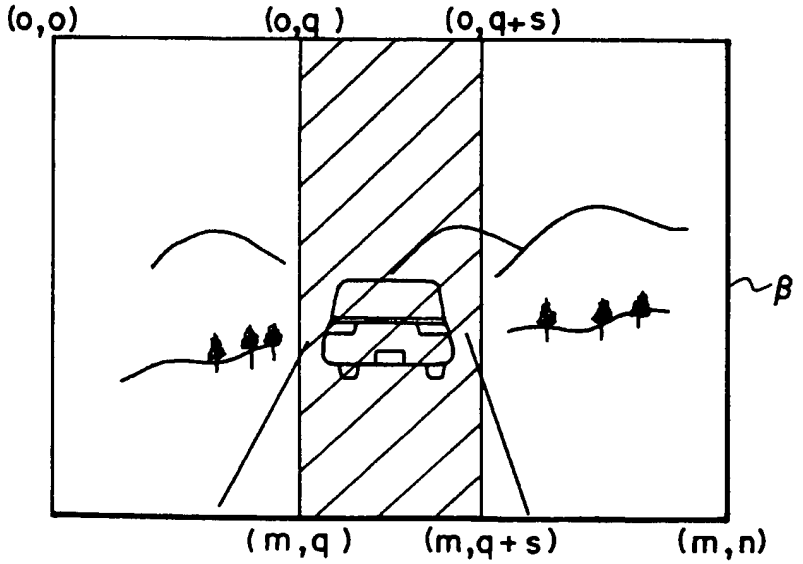


Fig.5

Fig.5A	Fig.5B

Fig.5A

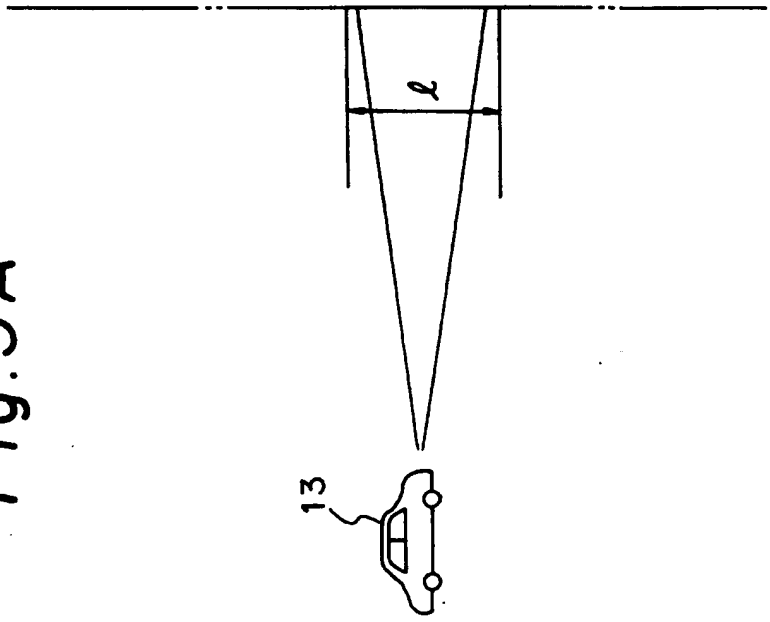


Fig. 5B

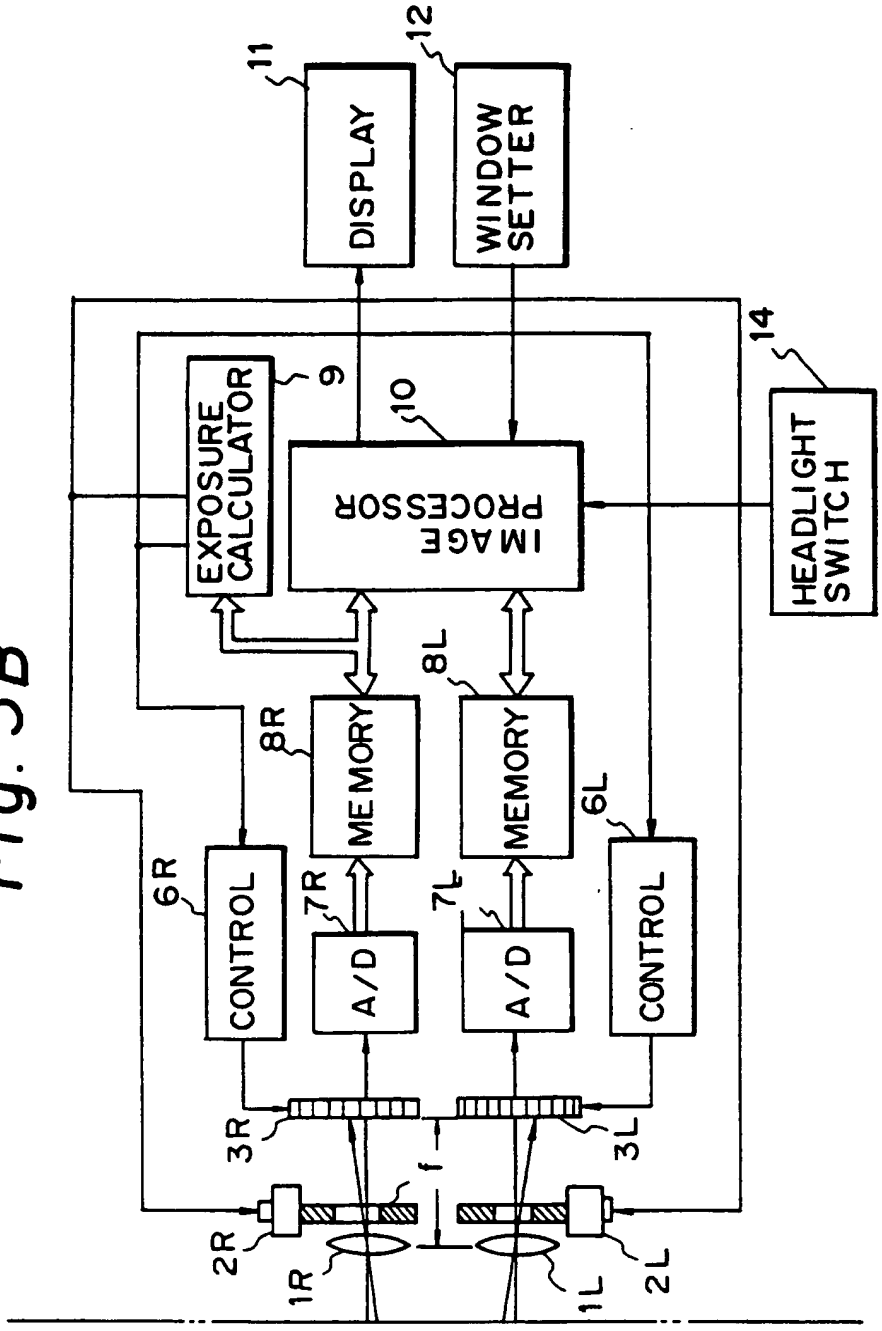

11
DISPLAY
12
WINDOW SETTER
14
HEADLIGHT SWITCH
9
EXPOSURE CALCULATOR
10
IMAGE PROCESSOR
8L
8R
MEMORY
MEMORY
6L
6R
CONTROL
CONTROL
7R
7L
A/D
A/D
3R
3L
f
2R
2L
1R
1L

Fig.6

Fig.6A	Fig.6B

Fig.6A

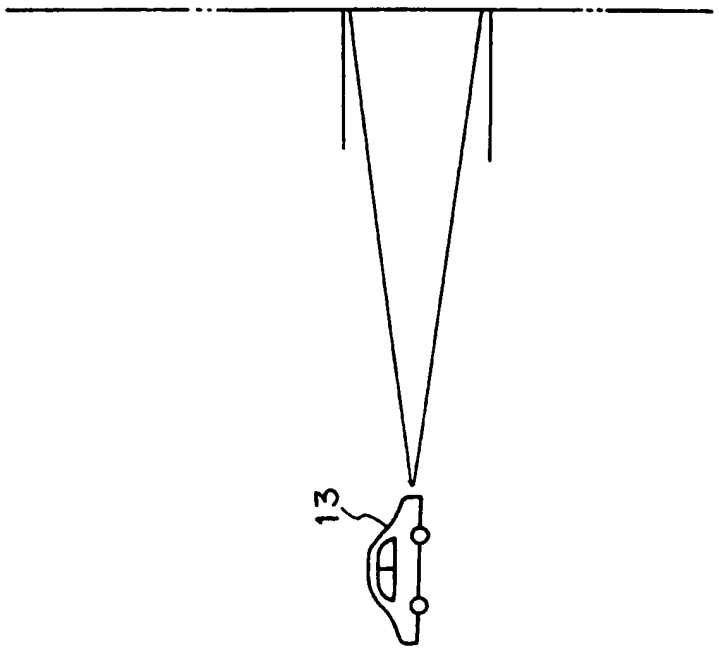


Fig. 6B

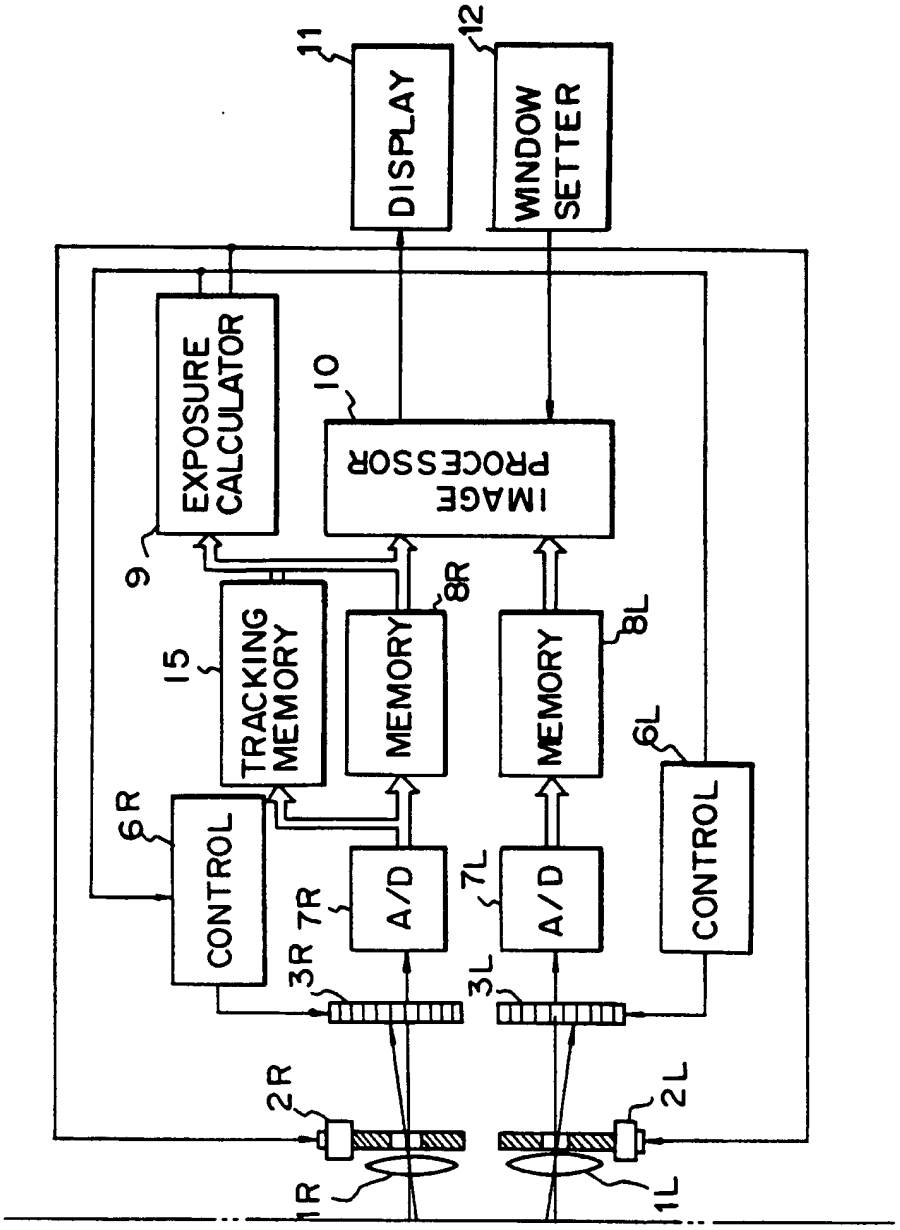

11
DISPLAY
12
WINDOW SETTER
EXPOSURE CALCULATOR
9
10
IMAGE PROCESSOR
15
TRACKING MEMORY
MEMORY
8R
MEMORY
8L
6R
CONTROL
A/D
3R 7R
A/D
7L
CONTROL
6L
3L
2R
2L
1R
1L

Fig.7

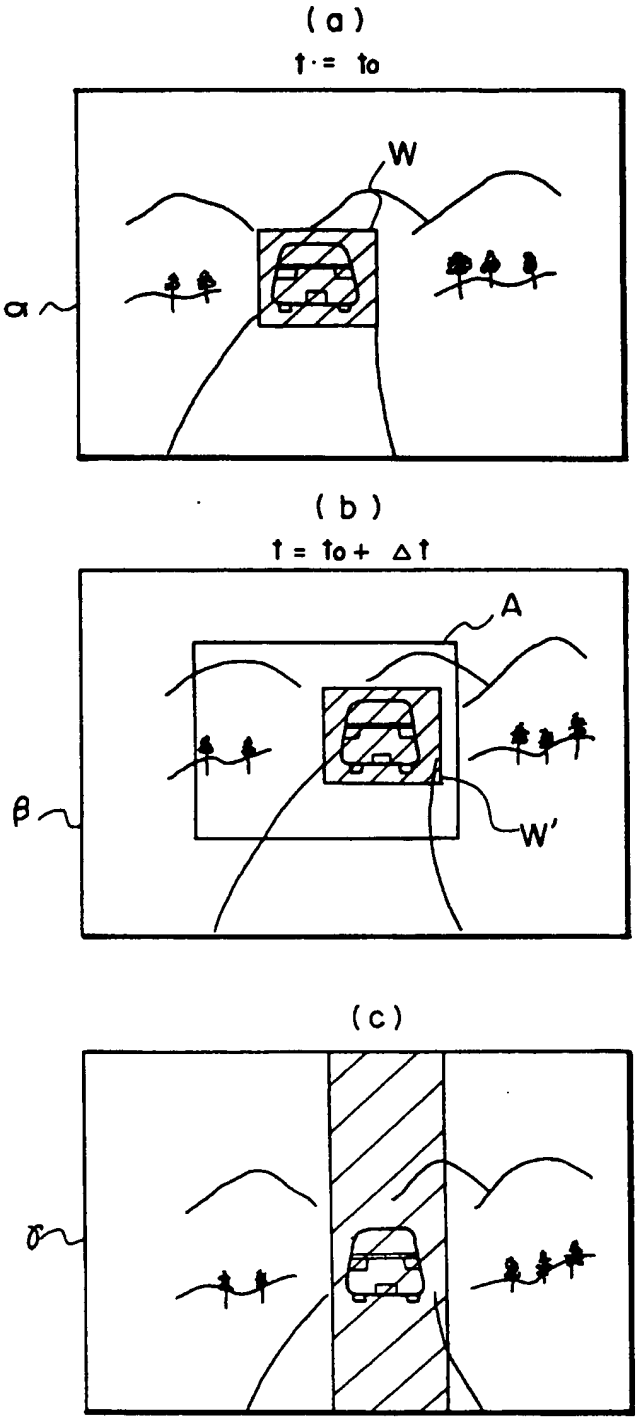


Fig.8

Fig.8A	Fig.8B

Fig.8A

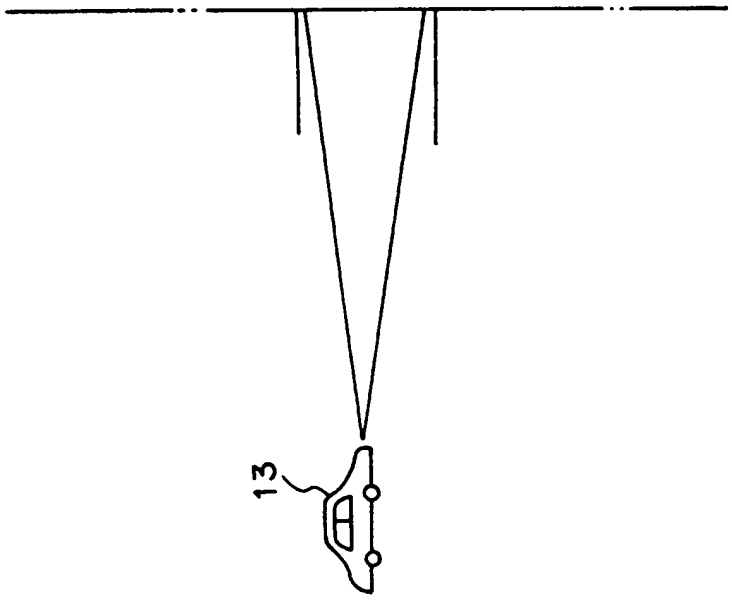
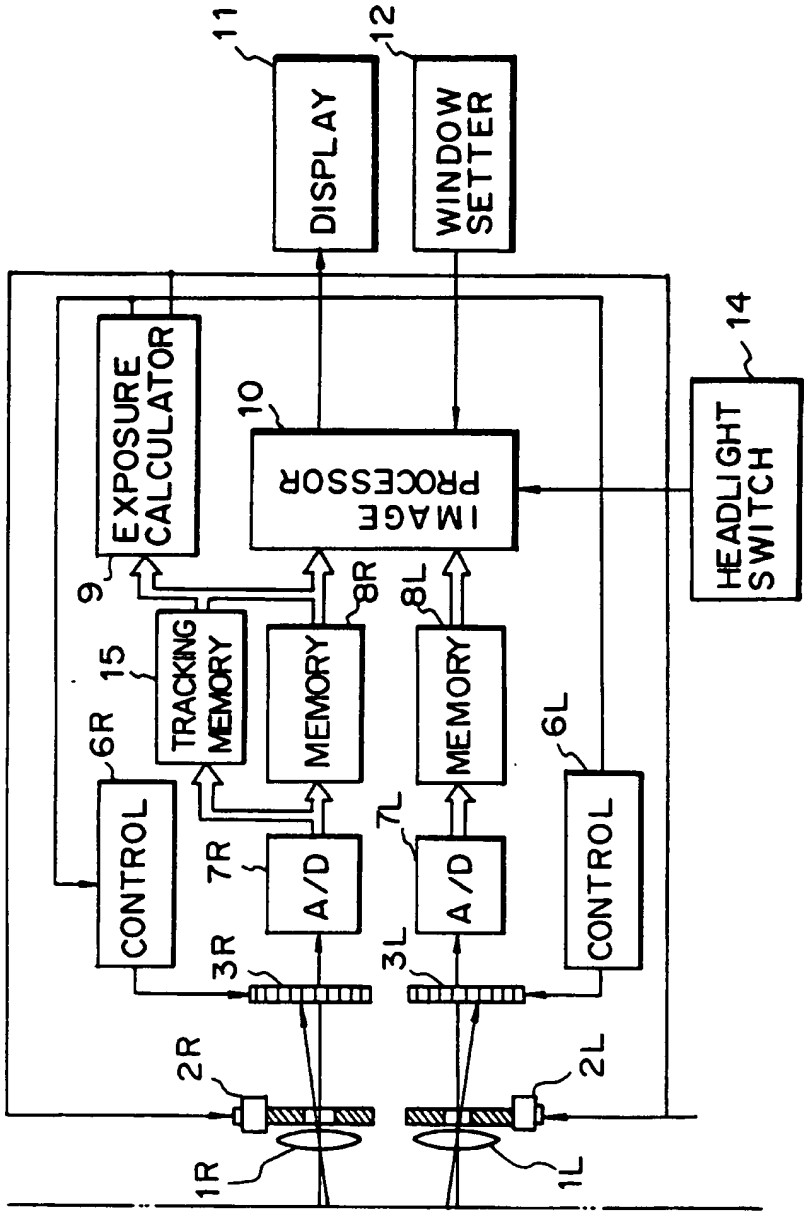


Fig. 8B


11
DISPLAY
12
WINDOW SETTER
14
HEADLIGHT SWITCH
10
IMAGE PROCESSOR
EXPOSURE CALCULATOR
9
8R
8L
15
TRACKING MEMORY
MEMORY
MEMORY
6R
6L
CONTROL
CONTROL
7R
7L
A/D
A/D
3R
3L
2R
2L
1R
1L